PERGAMON

Renewable and Sustainable Energy Reviews
5 (2001) 39–57

RENEWABLE
& SUSTAINABLE
ENERGY REVIEWS

www.elsevier.com/locate/rser

World Bank/GEF solar home system projects: experiences and lessons learned 1993–2000[1]

E. Martinot *, A. Cabraal, S. Mathur

World Bank, 1818 H St. NW, Washington, DC 20433, USA

Received 9 June 2000; accepted 13 June 2000

Abstract

Twelve projects provide energy services to off-grid rural households in developing countries by enhancing markets for solar home systems and by removing barriers to their dissemination. Project approaches are reviewed, along with early implementation experience and lessons suggested by experience. Most projects incorporate the following features: pilot private-sector and NGO delivery models; pilot consumer credit delivery mechanisms; pay first-cost subsidies and offer affordable system sizes; support policy development and capacity; develop codes and standards and establish certification, testing, and enforcement institutions; and conduct consumer awareness and marketing programs. Most projects are just beginning implementation; a few are almost completed. Lessons from early experience suggest that: solar home system delivery firms face a myriad of difficulties operating in rural areas; credit risk is a serious concern of both financiers and dealers and makes credit sales particularly challenging; technical performance of systems is becoming well-proven; customers desire a range of component options and service levels and can benefit from even small systems; projects must recognize the link between rural electric-grid extension and solar home system demand; and marketing campaigns can be extremely costly and time consuming in rural areas. Challenges are to demonstrate sustainable and replicable business models, develop regulatory models for energy-service concessions, and integrate rural electrification policy with solar home system delivery.

* Corresponding author. Tel.: +1-202-473-0169; fax: +1-202-522-3240.
E-mail address: emartinot@worldbank.org (E. Martinot).

[1] Eric Martinot conducted the work herein as an Associate of the Stockholm Environment Institute, Boston. He currently works for the Global Environment Facility. Anil Cabraal is a Senior Renewable Energy Specialist in the World Bank's Asia Alternative Energy Program. Subodh Mathur is a consultant to the World Bank and its Africa Rural and Renewable Energy Initiative. Views expressed are solely those of the authors and do not necessarily reflect official views of the World Bank or its client countries.

1364-0321/01/$ - see front matter
PII: S1364-0321(00)00007-1

1. Introduction

Since 1992, the World Bank Group has approved 12 projects that provide basic "energy services" such as lighting, radio, television, and operation of small appliances to rural households that lack access to electricity grids through the use of "solar home systems" (see Table 1).[2] A solar home system consists of a photovoltaic solar panel, a storage battery, a battery charging controller, and various pieces of end-use equipment like florescent lamps. Solar home systems can eliminate or reduce the need for candles, kerosene, liquid propane gas (LPG), and/or battery charging. Direct economic benefits include avoiding the costs of battery charging and LPG or kerosene purchases; other significant benefits include increased convenience and safety, improved indoor air quality, a higher quality of light than kerosene lamps for reading, and reduced CO2 emissions. Solar home systems already provide basic electricity services to more than 500,000 households in developing countries [1–6].

In the early 1990s, the World Bank recognized that solar home system technology was maturing, costs were declining, and commercial markets were developing. At the same time, population growth was outpacing the ability of electric utilities to extend rural electricity grids and developing countries were increasingly recognizing the economic difficulties of achieving full grid-based rural electrification. The World Bank and many governments began to perceive that solar home systems could provide least-cost rural electrification and could supplement grid-based electrification policies [7]. Because of the many obstacles to delivering solar home systems in rural areas, and because of the development and environmental benefits, the World Bank and Global Environment Facility (GEF)[3] have considered assistance for solar home systems to be highly relevant and have jointly supported these projects. In many projects, solar home systems are but one component of a larger project with a variety of development objectives like power sector reform, rural electrification, and rural development.

Solar home system project designs have continuously evolved with increased understanding of best practices. In general, projects are designed to overcome barriers to the widespread and accelerated dissemination of solar home systems in a given country context, such as:

- lack of an established market;
- lack of successful business models;
- lack of business financing and skills;
- unwillingness of utilities to provide off-grid electricity services;
- high transactions costs;
- high first cost and affordability;

[2] Some of these projects also target other applications of PV, such as agricultural, commercial and village power applications, which are beyond the scope of the present paper.

[3] For more information on the GEF, see [8] and the GEF web site: www.gefweb.org.

Table 1
World Bank group projects with solar home system (SHS) components

Project name	Approval dates and status	Bank/GEF funding and total project cost	SHS component description
India Renewable Resources Development Project	GEF: 1991 Bank: 1992 Under implementation	GEF: US$26 m Bank (IDA): US$115 m Bank (IBRD): US$75 m Total: US$450 m	2.5 MWp of PV in various applications (commercial, water pumping and SHS)
Small and Medium Scale Enterprise Program	GEF: 1994/1997 IFC: 1995 Under implementation	GEF: Vietnam: US$0.75 m Bangladesh: US$0.75 m Dominican Republic: US$75,000	Finance commercial SHS business ventures
Indonesia Solar Home Systems Project	GEF: 1995 Bank: 1997 Will be cancelled	GEF: US$24 m Bank (IBRD): US$20 m Total: US$118 m	200,000 SHS sold and installed by private dealers/entrepreneurs
Sri Lanka Energy Services Delivery Project	GEF: 1996 Bank: 1997 Under implementation	GEF: US$5.9 m Bank (IDA): US$24 m dealers and microfinance organizations	30,000 SHS sold and installed through
PV Market Transformation Initiative	GEF: 1996 IFC: 1998 Under implementation	GEF: US$30 m Total: US$90–120 m in India, Kenya and Morocco	Finance commercial SHS business ventures
Lao PDR Southern Provinces Rural Electrification Project	GEF: 1997 Bank: 1998 Under implementation	GEF: US$0.7 m Bank (IDA): US$1.5 m (for off-grid component only)	20 solar battery charging stations by national utility and village electricity associations as demonstrations
Argentina Renewable Energy in Rural Markets Project	GEF: 1997 Bank: 1999 Under implementation	GEF: US$10 m Bank (IBRD): US$30 m Total: US$121 m	66,000 SHS in households through regulated energy-service concessions
Cape Verde Energy and Water Sector Reform and Development	GEF: 1998 Bank: 1999 Under implementation	GEF: US$4.7 m Bank (IDA): US$17.5 m Total: US$48 m	4000 SHS in households through regulated energy-service concessions
China Renewable Energy Promotion Project	GEF: 1998 Bank: 1999 Under implementation	GEF: US$35 m Bank (IBRD): US$100 m Total: US$444 m	10 MWp of SHS and PV-wind hybrid systems installed through private dealers

(continued on next page)

Table 1 (*continued*)

Project name	Approval dates and status	Bank/GEF funding and total project cost	SHS component description
Solar Development Group	GEF: 1998 IFC: 1999	GEF: US$10 m IFC: US$6 m Total: US$50 m	Finance PV-related businesses and provide technical assistance and business services
Benin Off-Grid Electrification/ Traditional Energy	GEF: 1998 Bank: to be approved	GEF: US$1.1 m Bank: US$2.2 m Total: US$5.7 m	5000 SHS through regulated energy-service concessions
Togo Off-Grid Electrification/ Traditional Energy	GEF: 1998 Bank: to be approved	GEF: US$1.1 m Bank: US$2.2 m Total: US$5.7 m	5000 SHS through regulated energy-service concessions

- lack of consumer financing;
- uncertain technological track record;
- uncertain or unrealistic grid expansion plans; and
- other policy constraints like subsidies, tariff structures, and import duties.

The key elements of a sustainable rural PV market include customer satisfaction, affordability, dealer profitability, and effective supply and service chains. Considering these elements, most projects incorporate six basic features:

- pilot private-sector and NGO delivery models;
- pilot consumer credit delivery mechanisms;
- pay first-cost subsidies and offer affordable systems;
- support policy development and capacity;
- enact codes and standards and establish certification, testing, and enforcement institutions; and
- conduct consumer awareness and marketing programs.

Each project feature is intended to overcome a specific set of barriers. Projects take many different approaches to incorporating these features; some projects take more than one approach simultaneously to determine which approach is more effective or viable in the country concerned (see Table 2). Projects are essentially experimental because there simply is not enough accumulated experience yet from any institution, government, or firm to provide definitive answers about the best approaches. Elaborations of the six project features and emerging lessons from initial implementation experience are described in the following sections. The material that follows comes from World Bank project appraisal documents, unpublished reports, interviews with

Table 2
Project features and approaches

Project feature	Summary of project approaches	Key barriers addressed
1. Pilot private-sector and NGO delivery models	Private dealers or NGOs sell systems (Indonesia, India, Sri Lanka, Vietnam, Bangladesh, China) Energy-service companies (i.e., monthly fee-for-service) operate as regulated concessions (Argentina, Cape Verde, Benin, Togo) Energy-service companies (i.e., monthly fee-for-service) operate in an open market (Dominican Republic, India) Provide business information, training, and consulting services to private dealers, ESCOs and NGOs (Indonesia, Sri Lanka, China, Cape Verde, Argentina, Benin, Togo)	Lack of established market Lack of successful business models Lack of business financing and skills Unwillingness of utilities to provide off-grid electricity services High transactions costs
2. Pilot consumer credit delivery mechanisms	Offer consumer credit through dealers (India, Indonesia, Sri Lanka, Bangladesh, Vietnam) Offer consumer credit through established microfinance (microenterprise) organizations (Sri Lanka) Offer consumer credit through local development finance organizations (Vietnam)	High first-cost and affordability Lack of consumer financing High transactions costs
3. Pay first-cost-subsidies and offer affordable system sizes	Pay one-time-per-system subsidies, at levels either constant over life of project (Indonesia, Sri Lanka, China) or declining over life of project (Argentina, Benin, Togo, Cape Verde) Specify and sell smaller, more affordable systems (Indonesia, Sri Lanka, China, Cape Verde, Benin, Togo)	High first-cost and affordability Lack of an installed base ("critical mass") that would enable after-sales service activities to be profitable and would lower marketing costs
4. Support policy development and capacity	Provide technical assistance to national regulatory agencies for concession bidding and contracting and regulation of concessions (Cape Verde, Argentina, Benin, Togo) Build capacity of public renewable energy agencies (India) Incorporate solar PV into rural electrification policy and planning (Sri Lanka) Lower import duties (Sri Lanka, China)	Lack of experience regulating rural energy concessions High import duties Unrealistic political promises of grid extension Uncertain rural electrification policies

(continued on next page)

Table 2 (*continued*)

Project feature	Summary of project approaches	Key barriers addressed
5. Enact codes and standards and establish certification, testing, and enforcement institutions	Develop equipment standards for use in project-financed installations (Indonesia, Sri Lanka, China, Benin, Togo)	Poor system quality Uncertain technological track record Lack of information about product quality and performance
	Provide support for certification and testing agencies and laboratories (Indonesia, China)	
	Provide capacity building for dealers to meet standards and for regulatory agencies or financiers to verify compliance with standards (Indonesia, Sri Lanka, China, Benin, Togo)	
6. Conduct consumer awareness and marketing programs	Conduct promotional ads on TV and radio	Uncertain technological track record Lack of information about products, costs, and benefits
	Distribute information at local fairs and community events	
	Conduct door-to-door marketing	

World Bank staff, and interviews with project managers and stakeholders during visits to many of the countries involved during the period 1998–99.

2. Pilot private-sector and NGO delivery models

Projects have employed two basic private-sector models for delivery of solar home systems: “dealer sales” and “energy-service company”. A dealer-sales model means that a dealer purchases systems or components from manufacturers and sells them directly to households, usually as an installed system, and sometimes on credit (as in Indonesia, India, Sri Lanka, Vietnam, Bangladesh and China). The household owns and is responsible for servicing the system, although the dealer may provide service contracts or guarantees. An energy-service-company (ESCO) model means that the ESCO owns the system, charges a monthly fee to the household, and is responsible for its service. The ESCO may be a monopoly concession regulated by the government to serve specific geographic regions (as in Argentina, Benin, and Togo), or it may operate competitively without any explicit monopoly status (as in the Dominican Republic). Combinations of these two forms of ESCO start with monopoly concessions and progressively open up markets to competition after some years (as in Cape Verde).

The India project has promoted sales of photovoltaic systems through large indus-

trial enterprises, which could take advantage of favorable government tax credits, but these enterprises have focused on commercial markets. At the same time, small dealers financed through the project began to develop rural distribution systems and sell to rural households. ESCO models are also being employed. In Indonesia, a dealer-sales model has been employed. Dealers can participate in the project based upon eligibility criteria, such as existing business competence, sales/service infrastructure in related rural markets, and a credit agreement with a participating bank. The China project also uses a dealer-sales model and supports the development of local dealers similar to the Indonesia project. Any dealer in China who passes the project's eligibility criteria will be able to participate in the project (at least 10 dealers are expected initially; others may become eligible later). An ESCO concession model was considered unworkable in China and was rejected early in project design, partly because no appropriate authority exists, in either the electric power or agricultural/rural sectors, to regulate concessions.

In Argentina, the regulated ESCO concession model is used, partly because Argentina already had substantial experience with regulatory frameworks for concessions in other sectors. Also, the low percentage of households which remained unelectrified led the government to believe that the "bundling", economies of scale, and lower transaction costs possible with rural energy concessions were necessary to attract the private sector. The World Bank project is part of a broader, nationwide rural electrification program, in which rural energy concessions were already established in two provinces. Under the project, eight provinces have agreed to participate. For each of these eight provinces, the government awards a monopoly concession based upon a competitive selection process. The concession provides and maintains solar home systems (or other technologies it chooses) for households and collects a monthly fee-for-service. Concessions will be committed and obligated to provide electricity services (upon request from customers) to populations in a specific province over a period of at least 15 years [9].

Potential advantages of the concession approach are:

- can attract larger, better organized private companies with their own sources of financing;
- has the potential to serve a large number of customers in just a few years;
- has the potential to reduce equipment costs (through volume discounts), transaction costs, and operation and maintenance costs (through economies of scale); and
- ensures service to the customer over a long period (e.g., 15 years).

Potential disadvantages include:

- regulation may be costly and require substantial regulatory capacity;
- lack of competition may stifle innovation, new products and services, and cost reductions;
- technological change can undermine regulatory and contractual conditions;
- quality of service may be difficult for regulatory agency to ensure; and

- monthly fee collection costs may be high.

The government of Argentina is still exploring how best to regulate concessions and the project will help to pilot regulatory models and approaches. Two key issues are tariff structures (including tariff levels, government subsidies, negotiation procedures, and how often tariffs are reviewed and renegotiated) and the question of how to regulate the quality of service provided to customers by the concessions (i.e., provisions in contracts between concessions and their customers).

Following Argentina, three more recent projects in Benin, Togo, and Cape Verde also use the ESCO concession model. The Benin and Togo projects each attempt to establish financially viable private-sector installation and service companies by the project's completion. Like Argentina, monopoly concessions would be granted for 15 years in targeted regions to the winners of a competitive selection.

The Sri Lanka project was designed to accommodate both dealer-sales and ESCO models. Both types of firms, as well as NGOs, were allowed to apply for business financing from commercial banks under the project. Early in the project one firm tried to operate as an ESCO for awhile but found the costs of monthly collections among the highly dispersed and remote rural populations to be high. The firm did not have sufficient rural infrastructure and standing in rural communities to handle collections effectively and efficiently. Rather, this firm and one other firm are focusing on direct sales facilitated by consumer credit from a microfinance organization (see next section on consumer credit delivery). Initially, an NGO also attempted to sell systems on credit it supplied, but ceased operations when it was unable to satisfactorily service and maintain the systems it had sold.

Availability of business financing is an important element of all private-sector delivery models. In Sri Lanka, dealers, NGOs and cooperatives are eligible to borrow from commercial financiers participating in the project. The two primary dealers in that country have had no difficulty in obtaining business financing under the project. That situation could change after the project, but the dealers do not expect much trouble because they believe commercial financiers' perceptions have changed about the profitability and risk of the business. Under ESCO delivery models, financing for ESCOs comes from either government or multilateral sources, but may be channeled through commercial financiers; in Argentina, ESCO concessions receive financing from provincial and federal government sources.

Two IFC projects are also providing business financing for solar home systems businesses, which may deliver systems under a variety of models. The PV Market Transformation Initiative provides business financing for companies in PV markets in India, Kenya, and Morocco through a competitive solicitation and selection of business plans. The Small and Medium Scale Enterprise Program (SME) is providing business financing for dealers in Bangladesh, the Dominican Republic, and Vietnam. The SME program also provides added incentives for firms to demonstrate sustainability; if firms generate profits they receive partial debt forgiveness. In Vietnam, the dealer has been selling systems on cash and credit terms, but as rural grid extension continues in Vietnam, the dealer is looking to an ESCO concession approach and hopes the government may consider supporting such an approach in the future.

In the Dominican Republic, the dealer has been developing a successful fee-for-service business model that targets 50% of the rural population and charges US$5–20 per month for electricity service from solar home systems. Through continuous tuning of its business model to maximize income and minimize expenses, this firm is approaching profitability and "proof of concept" for an installed base of 5000 systems. The firm is attempting to scale-up the business model to 25,000 systems but recurring overhead costs and slim profits make expansion difficult: "this is a lean margin business; you don't want to burden a US$1 million company with the overhead costs of building a US$10 million company" the firm said.

There is also a need to develop the commercial skills of delivery firms. Delivery firms may be small, inexperienced ventures, or existing firms operating in rural areas may decide to expand their product lines to include solar home systems but need training in PV technologies. In Indonesia, because dealer cash flow was a key constraint in selling solar home systems on credit, dealer training focused on how to develop business plans and approach banks for business financing. In Sri Lanka, grants to dealers covered up to 50% of external consultant costs for preparing project finance proposals for commercial financiers. The Sri Lanka project also has provisions for business support, but dealers have not requested much assistance under the project. In China, the project helps dealers to improve system quality (through cost-sharing of design, testing and certification), market their products, and provide warranties and after-sales service. In Cape Verde, project assistance to ESCOs covers business planning, technical training for staff and managers, distribution infrastructure, and market development and research.

Lessons from early experience suggest that solar home system delivery firms face a myriad of difficulties operating in rural areas. These low-margin firms must develop good business models and need flexibility from projects in doing so. Firms with rural experience and/or distribution infrastructure will do better. Most will benefit from training and support in obtaining business finance and other business skills; and, indirectly, projects can attract other potential distribution channels into the solar PV business (e.g., existing retailers of other goods or providers of other rural services). For regulated energy-service concessions, a government agency at an appropriate level must learn to serve as an effective regulator.

3. Pilot consumer credit delivery mechanisms

With a dealer-sales model, consumer credit is important for making systems affordable to rural households. Market studies associated with World Bank projects have revealed that the majority of rural households with an income of less than US$250/month and not connected to rural electricity grids typically pay US$3–15 per month for energy, in the form of candles, kerosene, battery charging and disposable batteries [10–12]. These surveys have revealed a household's willingness to pay for energy to meet the end-uses valued most, such as entertainment, information, and high-quality lighting. In a fee-for-service arrangement, monthly fees can be regu-

lated or set to levels competitive with these expenditures. However, dealer sales of solar home systems must overcome the first-cost barrier — their high initial cost relative to these conventional alternatives — and provide a means whereby households can continue to pay amounts roughly equivalent to their conventional energy purchases. Long-term consumer credit is one means to make monthly payments more comparable to conventional energy expenditures.

Consumer credit is provided through three primary mechanisms in World Bank projects: dealer-extended credit, credit through a microfinance organization, and credit through a local development finance institution.[4] Consumer credit through commercial firms was first tried in India. This project provided credit through IREDA to commercial firms. The firms were supposed to purchase systems from manufacturers (realizing substantial government tax credits in the process) and then sell the systems to rural households on credit. A separate service firm, under contract to the manufacturer, was supposed to provide marketing, installation, commissioning, and after-sales service. This approach proved infeasible because the commercial firms were unwilling to lend to rural households due to credit-risk and collection concerns.

In Indonesia, a dealer-credit model was introduced partly because of the prior success of a private dealer in Indonesia selling systems on credit. This entrepreneur was able to sell more than 4000 systems on credit. In the original project concept, business financing would be extended by commercial financiers to dealers, and then in turn dealers would extend consumer credit, at terms of up to 4 years, to their customers. The commercial banks would bear the dealer credit risk, and the dealer would bear the consumer credit risk. Dealer sales of 200,000 systems were targeted through this model. Unfortunately, the project was never implemented because of Indonesia's macroeconomic crisis and will now be canceled. So the expected experience with dealer-supplied credit there has not materialized.

The Bangladesh project demonstrates an initially successful application of the dealer-credit model. The (non-profit) dealer, Grameen Shakti, performs marketing, sales, service, credit provision, collections, and guarantees. Before receiving an IFC loan under the Small and Medium Scale Enterprise Program, Grameen Shakti could obtain financing for terms of 1 year only, so was able to extend consumer credit only for 1 year terms. This greatly limited customer demand. With the IFC loan, Grameen Shakti is able to extend 3-year credit to customers, which has made a large difference in its business. Grameen Shakti's credit terms and customers are quite different from traditional Grameen Bank microfinance terms and customers. Grameen Bank members, typically poorer households, receive microenterprise loans (for income-generation purposes only) of US$100 or 200, for terms of up to 1 year, at 20% interest. In contrast, Grameen Shakti loans are roughly US$500 for terms of up to 3 years, at 12% interest. Grameen Bank loans are regularly repeated, while Grameen Shakti loans are one-time. Thus, there is a clear distinction between "business microfinance" by the Grameen Bank for its members, and "consumer credit" by Grameen Shakti for customers purchasing solar home systems.

[4] For more on microfinance see [13,14].

Dealer credit was tried early in the Sri Lanka project but soon rejected by the dealers themselves. Dealers found collections too difficult and time consuming and favored (and led) the shift away from a dealer-credit or fee-for-service model to a microfinance model. Building a rural "service infrastructure" with technicians is a very different business from building a rural credit delivery and collection infrastructure, said the suppliers. "The success of credit depends on local connections, knowledge and institutions already in place" said one industry observer.

So the Sri Lanka project has instead turned to microfinance organizations for extending consumer credit, with one large national microfinance organization participating so far in the project. This microfinance organization borrows from the commercial financiers participating in the project and lends to customers. Customers purchase solar home systems from the dealers, who are responsible for marketing, sales, and after-sales service. The microfinance organization is responsible for collections. The microfinance organization and dealers coordinate expected sales and credit delivery. The credit provided by the microfinance organization for purchase of solar home systems is similar in kind to that provided for enterprise development. The microfinance organization typically offers microenterprise loans from US$100 to 600, with terms of up to 4 years at 24% interest; terms for solar home system loans are similar: US$500 with 20% down payment, terms of up to 5 years, and 24% interest rate. Sri Lanka has a long history of rural microfinance, which has greatly helped the viability of a microfinance model there.

In Vietnam, sales by a private dealer are assisted by a complex credit delivery scheme involving the Vietnam Women's Union (VWU), an NGO, and the Vietnam Bank for Agriculture and Rural Development (VBARD), a development finance institution. VWU markets the dealer's systems and performs collections for consumer loans provided by VBARD. The dealer installs systems and is responsible for service. VBARD provides credit, assuming risk for 75% of the purchase price. The dealer provides a collateralized guarantee to VBARD for 5–10% of the purchase price and the customer covers the remaining 15–20% as a down-payment. In case of loan default, the dealer repossesses and refurbishes the system and VWU finds a new buyer. VBARD can recover any losses involved with repossession from the dealer's collateralized guarantee. Credit terms to consumers are only 6–18 months, however, which limits demand. Despite instructions from the head office, some conservative branch managers of VBARD have been reluctant to participate; where this has happened, the dealer has extended consumer credit itself.

A cash sales model without credit is employed in China. Extending credit to rural households was not considered feasible given the almost complete absence of experience with consumer credit in general in China. However, the project provides flexibility so that dealers may also offer innovative payment mechanisms to increase affordability [15].

Lessons from early experience suggest that credit risk is a serious concern of both financiers and dealers and makes credit sales particularly challenging. Dealers are reluctant to extend credit to rural customers with little credit history, and credit administration and collections may be costly. Local financiers need to take some commercial risk to increase project sustainability but have the same concerns. Partial

credit guarantee schemes, microfinance lending, and partnering promise viable models to reduce risks. Longer credit terms stimulate demand by poorer households but increase risks. Some customers with seasonal income (i.e., paddy farmers with semi-annual harvests) may require credit repayment schedules tied to income (i.e., semi-annual rather than monthly). In general, projects should allow dealers flexibility to innovate new payment mechanisms to make systems more affordable. Finally, adequate after-sales service is key to credit repayment performance.

4. Pay first-cost subsidies and offer affordable system sizes

Besides providing consumer credit, some World Bank/GEF projects incorporate first-cost subsidies to reduce high-first-cost and affordability barriers. These subsidies are intended to reduce the initial payment and/or the monthly payments households have to make, with the objective of making monthly payments as equivalent to current monthly payments for conventional energy (e.g., kerosene and batteries) as possible. Grants are paid to delivery firms, to commercial financiers, or to microfinance organizations upon installation and proper inspection and documentation of a solar home system. Certification of installation is either done by the project or by commercial financiers. Subsidies are used in different ways in different projects. For example, in Sri Lanka, the microfinance organization providing consumer credit reduces the amount of each monthly credit repayment by a share of the subsidy. Subsidies are incorporated into projects in China, Indonesia, Argentina, Benin, Togo, Cape Verde, and Sri Lanka.

Some projects offer fixed cash grants for each system installed. In China, a cash grant equal to US$1.50/Wp of installed capacity is paid directly to the dealer. In Sri Lanka, a US$100 grant is paid to the commercial financier. In Indonesia, grants of US$75 in Java and US$125 elsewhere are paid directly to dealers after the project receives documentation of customer acceptance of installation and a completed hire-purchase contract between the customer and dealer. Originally only 50 Wp systems were eligible for these grants in Indonesia, but in consideration of customers who want to purchase smaller, more affordable systems, the grants were extended to cover 30 Wp systems as well. The Indonesia project required that dealers offer credit to their customers as a condition of eligibility to receive the grant, which caused problems among dealers who did not want to borrow or extend credit. This requirement has become a problem in Sri Lanka as well, where one dealer was purchased by a large multinational corporation and thus no longer needs commercial financing, but must obtain financing under the project in order to qualify for grants.

Declining cash grants on a sliding scale over the life of the project are built into more recent projects. The idea of declining grants is that as the project gets closer to completion, existing businesses will be able to offer cheaper systems to customers, and thus smaller grants are needed for the same levels of affordability. For example, in Argentina, the ESCO concessions are given a variable cash grant for each system installed during the initial 5 years of the project, upon certification by the provincial

government that the system has been installed in accordance with pre-established standards and conditions. The cash grant declines for installations made in later years of the project and also depends upon system size. The grants decline gradually to zero by the end of the project. In Benin, Togo, and Cape Verde, declining grants similar to those of Argentina were also enacted. One drawback to providing grants on a sliding scale is the added administrative complexity of tracking systems in terms of when they are installed and thus for what level of subsidy they are eligible.

Many projects specify a minimum system size of 50 Wp. However, some projects allow sales of smaller-size systems or lower-cost components initially, and provide trade-in or resale mechanisms for consumers to “trade up” to more expensive systems. The Sri Lanka project has modified system specifications to allow more affordable systems of capacity 30 Wp and less to be eligible for GEF grants under the project. Most sales in Sri Lanka have in fact been of 32 Wp systems (selling for about US$450). Indonesia also modified specifications to allow 30 Wp systems. In China, systems as small as 10 Wp are allowed as long as components meet the relevant standards. Sales of 50 Wp systems predominate in Bangladesh, where the dealer has been able to achieve very low system costs of roughly US$500 for a 50 Wp system because of cheaper domestically produced components and favorably-priced PV module purchases.

Lessons from early experience suggest that customers desire a range of component options and service levels and can benefit from even small systems (such as 20–30 Wp). Even with subsidies and smaller systems, customers in early market phases may still be limited to the wealthiest rural households.

5. Support policy development and capacity

Several policy-related issues have factored into project design and experience:

Regulatory assistance for concessions. For projects using the ESCO concession model, technical assistance to national regulatory agencies is also included for concession bidding and contracting, training of agency staff, and monitoring and regulation of concessions. Examples of regulatory agencies are the provincial governments in Argentina; the national energy agency (INERG) in Cape Verde; and the Agence d’Electrification Rurale (AER) in Benin and Togo. In Argentina, sustainability is enhanced by strengthening provincial regulatory functions and institutions and appropriate incentives and returns for the concessions.

Rural grid extension planning and policy. Projects indirectly or directly influence government planning and policy related to rural electrification. For example, in Sri Lanka, the project has encouraged the national electric utility and the government to more explicitly recognize and incorporate solar home systems into rural electrification planning, and to recognize that unrealistic political promises and uncoordinated grid extension harm the market for solar home systems. Such encouragement may lead the national electric utility to admit to populations in specific rural areas that “the grid isn’t coming; consider a solar home system instead” (or even, “we will provide you with electricity, it just won’t be grid-based”).

Electric power sector reform. Power sector reform activities associated with other World Bank projects bear on future solar home system markets. For example, power sector reform in Sri Lanka will result in the establishment of an “independent utility regulator” accountable to parliament. When this happens, the World Bank expects to see more realistic grid expansion plans for rural areas, greater accountability, and fewer false promises by politicians. This should help stabilize and solidify geographic areas of solar home system demand.

Industry participation in policy and planning. In Sri Lanka, a project workshop led to the creation of a solar energy industries association, with eligibility limited to dealers who have a proven sales record. In part this association formed to act as a unified voice for companies to interact with the World Bank, the government, and the national electric utility on project matters and rural electrification policy and planning.

Import duties. Reduced import duties on PV components can remove market distortions and make solar home systems more affordable for rural households. The government of Sri Lanka reduced import duties in conjunction with the project from 30 to 10% (10% is duty for all other non-protected goods). (Ironically, the 30% import duty was originally designed to protect a domestic PV manufacturing plant, but when that plant was closed (prior to the project), the import duty served to depress the emergence of a PV dealer industry using imported components.) In China, import duties were eliminated for PV components in conjunction with China’s policy that all government-approved renewable energy projects can import materials duty free (although most components are expected to be produced domestically because China has a large PV industry).

Lessons from early experience suggest that concession tariff-setting, bidding and regulation present numerous challenges and require substantial time and resources. Projects must recognize the link between rural electric-grid extension and solar home system demand; customers’ perceptions of future rural electric grid extensions, whether based upon concrete government plans or merely unrealistic political promises, can limit demand for solar home systems. Thus clear, open and realistic rural electrification policies can help create and/or stabilize market demand. All else being equal, consumers are going to prefer being connected to the grid rather than receiving energy services from a solar home system. However, there is added value from solar home systems if customers have to wait some years for the grid to arrive.

6. Enact codes and standards and establish certification, testing and enforcement institutions

Historically, the reasons for failure of solar home systems projects included poor quality products, poor installation and maintenance, and systems being “oversold” (marketing claims that raise expectations higher than the technology can deliver). Codes, standards and certification (and marketing restraints) are important elements to address these issues, as well as reduce commercial risks.

Enforcement of standards, including associated institutional capacity, is equally important. During a World Bank project, the project itself can ensure that standards are enforced. After project completion, this task will be left to the government and/or institutions created or strengthened during the project. Since no projects have been completed yet, post-project enforcement of standards (and voluntary adoption by firms) has yet to be tested.

Most projects develop and establish PV component and systems standards to ensure quality, safety and long-term reliability. Dealers who wish to participate in the project must then get their equipment certified at an approved testing laboratory. For example, in the Benin and Togo projects, the rural electrification agency issues and enforces a "PV code of practice" and technical standards. In Indonesia, dealers are required to furnish certifications from acceptable testing facilities that their components meet or exceed the selected specifications before they can sell. Assistance is provided to participating dealers to get equipment certified by international laboratories. The China project hopes to develop and disseminate equipment standards so they are adopted outside the project, as a proposal for national standards. National certification in China could indirectly encourage certified Chinese products to be sold internationally, similar to what is happening in Indonesia — products certified under the World Bank project are being sold to other countries.

Sri Lanka at first adopted the standards used in Indonesia, but then modified the standards to allow smaller systems (down to 20 Wp) better suited to Sri Lanka consumer demand and solar insolation characteristics. Later, in both Indonesia and Sri Lanka, minimum requirements were further reduced due to consumer demand and dealer capabilities.

In Sri Lanka, equipment certification held up the project for the first year as there were no certified products available to sell. The project design did not expect that it would take nearly this long to get certified products into the hands of suppliers, perhaps because the project originally thought the systems would be imported from Indonesia, where presumably a market based around World Bank approved standards was to have developed in parallel with the Sri Lanka project. Even then, batteries would not meet the established specification and the Sri Lanka project had to declare a moratorium on the battery specifications for several additional months.

Domestic certification and testing agencies are also important. The Indonesia project provides technical assistance for strengthening capabilities of the Agency for the Assessment and Application of Technology for solar PV testing and certification. In China, grants provide equipment and training to create a national PV Testing and Certification Center. Assistance is also provided to strengthen PV module and balance-of-system testing and certification agencies, as well as strengthening the capabilities of a design-assistance center.

Most projects also provide capacity building to ensure quality systems are installed. This assistance is important not only to protect consumers under the project, but also the reputation of an industry striving towards large scale commercialization. In Sri Lanka, assistance to dealers was planned for testing and quality improvements, but dealers did not appear to need or be interested in such assistance. In Sri Lanka, grant funds are also available to commercial financiers to verify that solar home

system designs meet project specifications and that systems are installed properly. Grant funds also maintain a facility for investigating unresolved consumer complaints against dealers and seeking appropriate solutions. In China, capacity building is provided for quality assurance and consumer protection. In Benin and Togo, the rural electrification agency will develop the capability to spot check installed systems and conduct regular consumer surveys to ensure good technical performance of private operators.

Few technical problems have been encountered with systems. Lessons from early experience suggest that establishing reasonable equipment standards and certification procedures for solar home system components that ensure a quality service while maintaining affordability is not difficult. Projects should allow some flexibility in standards to enable dealers to meet them. Standards should be used only to the degree to which they contribute to adequate consumer satisfaction and thus a sustainable market, but not so as to excessively stifle the market.

7. Conduct consumer awareness and marketing programs

Most projects conduct some type of consumer awareness and marketing program. Such programs are usually preceded by a market survey conducted as part of project preparation activities (such as in India and Indonesia) or by an existing market survey done by others (such as in Sri Lanka). The China project conducted an extensive survey of rural consumers to better understand the market because there was very little existing demographic data (including population, income, expenditures, household structure, etc.) available on which to base project strategies. Surveys of a sample of 2000 households, including existing owners of solar home systems, revealed important information about affordability and household budgets. The China project also provides grants to dealers to assist them with sales and marketing activities.

In India, IREDA has been conducting promotional campaigns for PV technologies in the media, but these campaigns may not have reached rural households. Within the Sri Lanka marketing program, the project hired a consultant specifically to lead village-level workshops throughout the country to promote solar home systems. In these workshops, dealers are able to demonstrate their products and village leaders learn about the technology. In addition, potential local microfinance organizations have learned about the project and gauged local interest in solar home systems, and have been invited to participate in the project and provide consumer credit to the local community. Such workshops were being conducted twice monthly and were considered moderately successful, although dealers felt the workshops did not sufficiently attract the actual customers of solar home systems.

Projects also support ESCO concessions in their marketing and consumer awareness activities. In Argentina, provincial governments assist concessions by preparing detailed market studies, conducting information dissemination workshops, and preparing studies on how to improve the availability of DC appliances compatible with solar home systems in dispersed rural areas. In Benin and Togo, the rural electric

utility conducts marketing activities to support the ESCOs; the utility polls communities on their interest in solar home systems and willingness to pay, and collects information on the demographics of these villages. In addition, ESCOs can conduct market surveys themselves using project grants.

Lessons from early experience suggest that marketing campaigns can be extremely costly and time consuming in rural areas, often requiring door-to-door and direct contact. Simple consumer awareness is usually insufficient by itself. Dealers benefit from marketing assistance in early phases of new market development until a "critical mass" of customers develops that makes marketing easier.

8. Conclusion

In all projects, demonstration of a viable business model, whether that business is public or private, is key to achieving project sustainability and replication. Viability means clearly showing expenses and receipts, cashflow, profits (or required subsidies), and management arrangements that demonstrate a business can continue to exist and function. "There is a high value-added [by projects] in terms of developing and improving business models … you want to stimulate markets based on these business models" said a dealer in one project. For commercial firms, profit is the ultimate measure of whether a business model is viable and whether to operate in a given market. For non-profit organizations or public firms (i.e., public utilities), ongoing subsidies may be part of the business model based on public objectives (e.g., rural electrification and development). All projects in some way help firms maximize income (related to demand, pricing and affordability) and minimize expenses (for marketing, service, training, and operations).

Most World Bank Group projects are relatively new and offer little implementation experience so far. Five leading projects in Bangladesh, the Dominican Republic, India, Sri Lanka and Vietnam have installed more than 8000 systems.[5] There is still a long way to go; installation targets from all projects total more than 500,000. Beyond these direct results, indirect market impacts will also be important to assess in coming years [16]. Commercial sustainability and replication of viable models has not yet been achieved or conclusively demonstrated in any World Bank project.[6] It is simply too early in the evolution of the portfolio. Further implementation pro-

[5] Most of these installations are stand-alone solar home systems, except in India, where 1500 solar lanterns provide light to rural households and five village-power schemes of 25 kWp each are supplying electricity to 500 families.

[6] There are several examples of successful commercialization of solar home systems that have occurred without much direct donor assistance, notably in China, Indonesia, Kenya and Zimbabwe. These cases also illustrate alternative delivery models that are not dedicated solar PV businesses, like battery companies and sellers of household goods in Kenya and household furnishing chains and hardware/electronics stores in Zimbabwe. Additional assistance from UNDP/World Bank ESMAP and other donors has further facilitated some markets [4,17–19].

gress for all projects is needed before more definitive conclusions can be drawn about experience, lessons, and effective project designs.

Challenges for the future include continuing to demonstrate viable business models, developing regulatory models for energy-service concessions, and integrating rural electrification policy with solar home system delivery. Future projects need to draw from emerging lessons in the current portfolio, incorporate flexibility and adaptation, and allow sufficient time to develop and test viable models.

Acknowledgements

This paper has been prepared with support from the Climate Change Thematic Group and the Asia Alternative Energy Program of the World Bank, and from the Global Environment Facility.

References

[1] Foley G. Photovoltaic applications in rural areas of the developing world. World Bank technical paper no. 304. Washington, DC, 1995.
[2] Cabraal A, Cosgrove-Davies M, Schaeffer L. Best practices for photovoltaic household electrification programs: lessons from experiences in selected countries. World Bank technical paper no. 324. Washington, DC, 1996.
[3] Cabraal A, Cosgrove-Davies M, Schaeffer L. Accelerating sustainable photovoltaic market development. Prog Photovolt Res Appl 1998;6:297–306.
[4] Kammen D. Promoting appropriate energy technologies in the developing world. Environment 1999;41(5):11–15, 34–41.
[5] Loois G, van Hemert B, editors. Stand-alone photovoltaic applications: lessons learned. London: James and James, 1999.
[6] Kaufman S. Rural electrification with solar energy as a climate protection strategy. Renewable Energy Policy Project research report no. 9. Washington, DC, 2000.
[7] World Bank. Rural energy and development: improving energy supplies for 2 billion people. Washington, DC, 1996.
[8] Martinot E, McDoom O. Promoting energy efficiency and renewable energy: GEF climate change projects and impacts. Washington, DC: Global Environment Facility, 2000.
[9] Martinot E, Reiche K. Regulatory approaches to off-grid electrification and renewable energy: case studies from developing countries (draft). Washington, DC: World Bank, 1999.
[10] Global Environment Facility. Argentina: renewable energy in the rural market. Project document. Washington, DC, 1998.
[11] Global Environment Facility. Sri Lanka: energy services delivery. Project document. Washington, DC, 1998.
[12] Global Environment Facility. Benin: decentralized rural energy. Project brief. Washington, DC, 1998.
[13] Dicter T. Case studies in microfinance. Washington, DC: World Bank, 1999.
[14] Ledgerwood J. Microfinance handbook: an institutional and financial perspective. Washington, DC: World Bank, 1999.
[15] Taylor RP, Bogach VS. China: a strategy for international assistance to accelerate renewable energy development. World Bank discussion paper no. 388. Washington, DC: World Bank, 1998.
[16] Martinot E. Monitoring and evaluation of market development in World Bank–GEF climate change

projects: framework and guidelines. World Bank Environment Department paper no. 66. Washington, DC, 1998.
[17] GTZ. Basic electrification for rural households: experience with the dissemination of small-scale photovoltaic systems. Eschborn, Germany: Deutsche Gesellschaft für Technische Zusammenarbeit, 1995.
[18] van der Plas RJ, Hankins M. Solar electricity in Africa: a reality. Energy Policy 1998;26(4):295–300.
[19] ESMAP. A review of the renewable energy activities of the UNDP/World Bank Energy Sector Management Assistance Programme 1993–1998. Washington, DC: World Bank, 1999.